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FROZEN APPLE-JUICE CONCENTRATE: Application of Laboratory Data to Prospective Commercial Operations

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A method for commercial production of a full-flavored apple-juice concentrate is proposed, on the basis of laboratory data. The important processing steps are discussed, a flow sheet is presented, and estimates of probable plant investment and processing costs are given.

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FROZEN APPLE-JUICE CONCENTRATE: Application of Laboratory Data to Prospective Commercial Operations

Laboratory studies in the Bureau of Agricultural and Industrial Chemistry on the production of a full-flavored frozen apple-juice concentrate have resulted in many inquiries from grower organizations and processors. To assist in answering their questions, we have prepared this progress report, which is concerned with application of completed laboratory studies to commercial operation. Much experimental work remains to be done, and changes in the process and cost estimates may be indicated when further information is available.

Three methods for the commercial processing of full-flavored frozen apple-juice concentrate are described by Walker, Nimmo, and Patterson (7).[1] Basically, the preparation procedures are:

1. Apple juice is concentrated six-fold, and the concentrate is mixed or "cut back" with fresh juice to produce a four-fold concentrate.

2. Essence is stripped from fresh juice and concentrated, the residual juice is concentrated to slightly over four-fold, and the essence is returned to this concentrate to produce a four-fold product.

3. Essence is stripped from fresh juice and concentrated, the residual juice is concentrated to six-fold, and the essence returned to this concentrate. The product is then diluted to four-fold with fresh apple juice.

The first method corresponds to the commercial method now being used successfully to prepare high-quality citrus-juice concentrates. However, it was found that apple-juice concentrate made by this procedure was weak in natural apple-juice flavor and inferior to that produced by the second and third methods. The second and third methods produced desirable full-flavored products, differing little or not at all from each other, so the choice of a process must be based on other factors.

Both methods involve essence stripping, which has been described by Milleville and Eskew (3,4,5). A modification of this essence stripping operation by imposing a steam injection heater prior to the conventional tubular heater is being suggested by Brown, Lazar, Wasserman, and Ramage (1). As the latter report points out and as shown by Milleville and Eskew (4), essence stripping does an excellent job of sterilizing.

Contamination may occur after stripping; therefore neither method gives a sterile product as packaged. However, in the second process all juice passes through the essence stripper and all bacterial life that enters with the fruit or is introduced in pressing is killed. In the third method, fresh apple juice, which does not go through the essence stripper, is used for blending. This juice may carry over to the finished product any bacterial contamination entering with the fresh juice or introduced in the pressing operations. As these appear to be the greatest sources of contamination, the second method offers the definite advantage that it produces a more nearly sterile product.

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[1] Numbers in parentheses refer to literature cited on page 7.

Pasteurization of fresh juice used for blending in the third method would be equally effective in preventing contamination from pressing operations or raw material. However, added cost for pasteurization is not compensated by any advantage over running all juice through the essence stripper.

Both the second and third methods involve evaporation of the same amount of water per unit of product, but the third method involves the production of a six-fold concentrate. Lower heat-transfer rates are encountered in concentration from four-fold to six-fold than from single-strength to four-fold. Evaporation costs are, therefore, slightly higher in the operation requiring a six-fold concentrate.

For these reasons, the second process appears to be the most desirable and has been used as the basis for our estimate of costs in a commercial operation.

Taste panel tests (6) on the reconstituted product, after storage of the concentrate for three and six months at 0°F., showed that the original fine flavor was well retained. Informal tastings at approximately nine months of storage have confirmed the conclusion that little or no change is taking place at that temperature. It should be mentioned here that canned heat-processed concentrates (flash-heated, filled, and cooled immediately after sealing) stored at 75°F. acquired an appreciable amount of off-flavor after three months' storage. The off-flavor was more pronounced after six months. These canned concentrates were from the same lot of concentrate as the frozen, and were of similar high quality directly after packing. Complete description of the storage tests will be published as soon as the twelve months' storage has been completed.

BASIS FOR ESTIMATES

In scaling-up laboratory data on apple-juice concentrate to commercial-sized operations, many assumptions have been necessary. These include:

Plant Size. A plant processing 3 tons of apples per hour has been chosen as a basis for calculations. With a 70 percent overall yield, the plant processes about 500 gallons of juice per hour. Assuming packaging in six-fluid-ounce cans (most common size for frozen citrus concentrates), production is 2,560 cans per hour. This size of plant is probably about the minimum that can operate economically. Even at this scale of operation, the capacity of available models of some standard machines is greater than needed. Efficient utilization of all labor may also be a problem.

Yearly Production. The assumption has been made that 4,000,000 six-ounce cans are produced yearly, in 1600 operating hours. The length of harvest season, feasibility of storing raw materials, and availability of the desired varieties will determine the actual operating season in a given situation. Many plants processing single-strength apple juice have much longer processing seasons than are assumed for this study. Further information correlating variety, storage time, and storage conditions with product quality is necessary for a decision on feasible storage periods for apples for making a high-quality frozen apple-juice concentrate.

Equipment and Processing Steps. All equipment in contact with juice is made of stainless steel. Juice holding temperatures are believed to be low enough to control bacterial growth for the holding times involved. The general design of the plant has been influenced by observation of equipment in citrus-concentrate plants. Many of the latter have invested heavily in excellent equipment. In view of the wide public acceptance of citrus concentrates, the heavy investment in equipment to insure high quality seems justified.

Many different cost figures may be obtained, depending on specific assumptions that are made. The cost figures shown with this report are only intended to give approximations of costs that are involved, thus indicating the major cost items.

PROCESS

The process as outlined on the attached flow sheet is divided into the following major operations: pressing, essence stripping, clarification, concentration, blending, freezing, and packaging. Quantities of materials involved are indicated by the figures enclosed in blocks.

Pressing is accomplished in the customary manner, with standard equipment readily available for this purpose. No changes from operations as performed for single-strength juice are required. Strict sanitary practices are recommended.

As previously noted, essence stripping has been described in published reports. The flow sheet follows the method of essence stripping used for pilot-plant work at the Western Regional Laboratory and described by Brown et al. (1). A steam injector preheats the juice so that chances of fouling the surfaces of the heat exchanger used for essence stripping are very low. When a heat exchanger is used alone for preheating and essence stripping, fouling may occur. If the surfaces of a heat exchanger are permitted to become too badly fouled by extended runs, the flavor of the finished product may be affected. The use of a steam injector for preheating does have some disadvantages. The steam must be free from tastes and odors to prevent off-flavor in the product, and the steam consumption is increased appreciably, because the steam that condenses in the juice must be evaporated later in the process. Further information is needed to evaluate fully the available methods of essence stripping.

After removal of essence, the residual or stripped juice is clarified by treatment with a pectic enzyme and filtration. Methods of clarifying fresh apple juice are described by Marshall (2). The operations as indicated on the flow sheet are those required to produce a clear juice for bottling and have been used in laboratory tests. A simpler method of clarification may prove feasible upon further investigation.

After clarification, the stripped juice is concentrated. As indicated by Walker, Nimmo, and Patterson (7), a low temperature, as used for citrus concentrates, is not required to prevent changes in flavor. A forced-circulation evaporator is indicated on the flow sheet. In view of the smaller dangers of localized overheating, with production of off-flavors, a forced-circulation

Table 1.--Apple juice concentrate, preliminary cost estimate

Plant capacity: 3 tons of apples per hour

Processing steps	Plant investment			Processing costs per hour
	Equipment	Building	Total	
Receiving and storing	$ 4,000	$30,000	$34,000	$ 7
Pressing	12,000	7,000	19,000	13
Essence stripping	17,000	3,000	20,000	5
Clarification	13,000	2,000	15,000	8
Concentration	21,000	2,000	23,000	6
Blending	3,000	1,000	4,000	1
Freezing	33,000	7,000	40,000	8
Packaging	10,000	5,000	15,000	61
General	3,000	10,000	13,000	9
Total	$116,000	$67,000	$183,000	$118

Table 2.--Processing costs by type of expenditure

	Estimated processing costs	
	Per hour	Per can
Labor	$28	$0.011
Utilities	2	.001
Supplies	65	.025
Charges based on investment	23	.009
Total processing costs	$118	$0.046

unit is recommended in preference to a pan or a calandria type of evaporator. Commercial runs in the latter types may indicate their complete suitability for this operation if controlled properly.

The concentrated stripped juice and essence are blended in agitator-equipped, cold-wall tanks. This operation is regulated on a volumetric basis. The solids content of the final product can also be adjusted in the same blending tanks. If the juice has been concentrated to a slightly higher degree than is required, the solids content in the final product can then be controlled accurately by dilution with a small amount of juice from the clarification operation. Automatic control may be feasible for this adjustment.

Although this discussion is based on concentration of fresh juice to one-fourth of its volume to make the finished concentrate, the desirability of standardizing the product on a solids-content basis should be considered. Apple juices vary widely in solids content, and four-fold concentrates made from different juices will vary correspondingly. Standardization of the concentrate on a solids basis will eliminate this variation.

The cost estimate assumes that the blended concentrate is cooled and 10 percent is converted to ice in a slush freezer. The product is then packed in cans and freezing is completed. Some operators might wish to operate without slush freezing, which is optional. Many commercial citrus-concentrate lines include this step to prevent any segregation in the frozen product and to help insure a high-quality product. Apple concentrate has been frozen quite satisfactorily in this Laboratory without slush freezing. If the slush-freezing step is eliminated, the tunnel freezer must be larger, and the canned product should be placed in the freezer without delay. Differences in operating costs with and without the slush-fredzing step are minor. A freezing tunnel or other type of freezer that can handle various sizes of cans is preferable to types that handle only one size.

The order in which the operations are performed, as shown on the flow sheet, may be modified by further laboratory work. Such changes will probably not make major differences in cost.

The flow sheet does not provide for blending of various varieties of apples that may be necessary to obtain the best possible juice. Two methods may be considered for accomplishing this purpose:

1. Partial control of blending can be attained by storage of fresh apples. Early fall varieties can be held for processing during the harvest season of the late varieties. It is doubtful that many early fall apples can be held for the latter part of the processing season.

2. Better control of blending can be attained by holding essence and stripped juice concentrate in frozen storage for later use in preparing desired blends. Holding from one operating season to the next is possible.

As discussed later, an allowance has been made for plant investment in storage facilities for fresh apples, but under certain conditions a part of this investment might better be made in facilities for essence and concentrate storage.

COST ESTIMATES

The cost estimate shown in Table 1 indicates the plant investment and processing costs based on prices for June, 1950. Plant investment is divided between equipment and building costs for each processing operation shown on the flow sheet. The building cost indicated for receiving and storage is primarily storage space for apples. Storage or other means to control plant raw material is essential if blending is necessary and a product of consistent flavor is desired. Some favorably located plants might not require their own storage facilities. The investment figures for essence stripping and for concentrating include steam and water-cooling facilities as well as those directly involved in the operations.

A total plant investment of $183,000 is indicated. This does not cover facilities for holding the finished frozen product for long periods.

Processing costs are divided on an operational basis in Table 1, on cost estimates. Packaging costs of $61 per hour are about half of the total processing costs of $118 per hour. Essence stripping and concentration, the two key operations in this process, are not high-cost operations.

In Table 2, unit processing costs are broken down by type of expenditures, and a cost of 4.6 cents per 6-fluid-ounce can is indicated. Labor includes direct processing labor and the supervisory labor that is directly associated with processing. Utilities cover electrical power costs. Fuel for steam generation is included in supplies. Charges based on investment cover interest, taxes, insurance, depreciation, and maintenance and repairs. Twenty percent of the investment is allowed per year for these costs and is prorated on the basis of 1600 operating hours, or 4,000,000 cans of concentrate produced annually.

The total processing cost as shown does not cover raw-material costs, raw material procurement, or sales costs. Approximately 2.35 pounds of apple are required per can of concentrate. Raw-material cost can be easily estimated when the price of apples is known.

Calculations of storage costs based on rates quoted in the San Francisco Bay area indicate that storage of a frozen concentrate costs less than storage of an equivalent amount of non-concentrated material at normal temperatures. On a weight basis, shipping costs, including refrigeration, may, for frozen commodities, run about 50 percent more than for non-refrigerated foods. Because apple concentrate weighs less than one-third of its original weight, the total freight cost for equivalent quantities is lower for the concentrated form.

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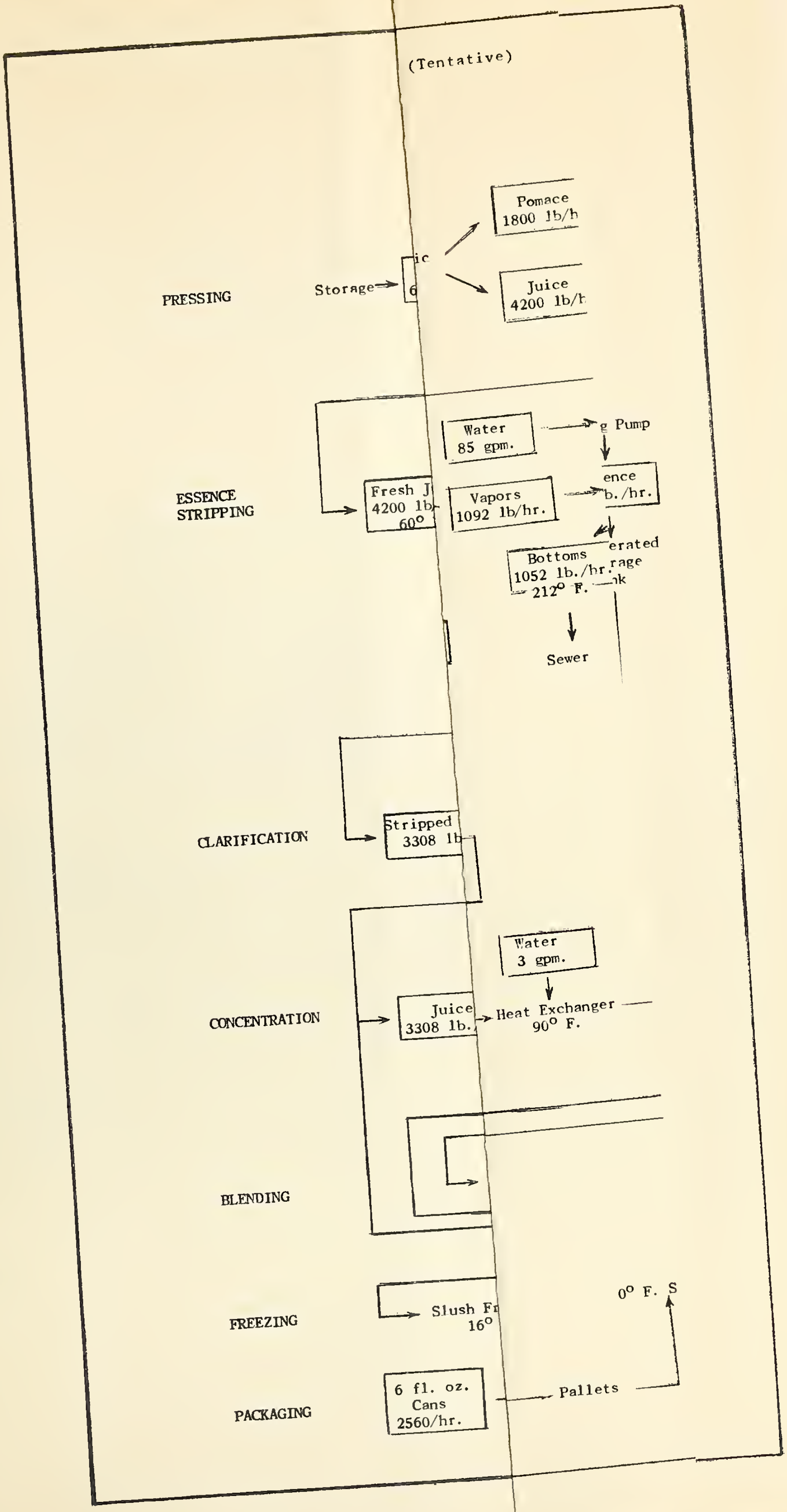

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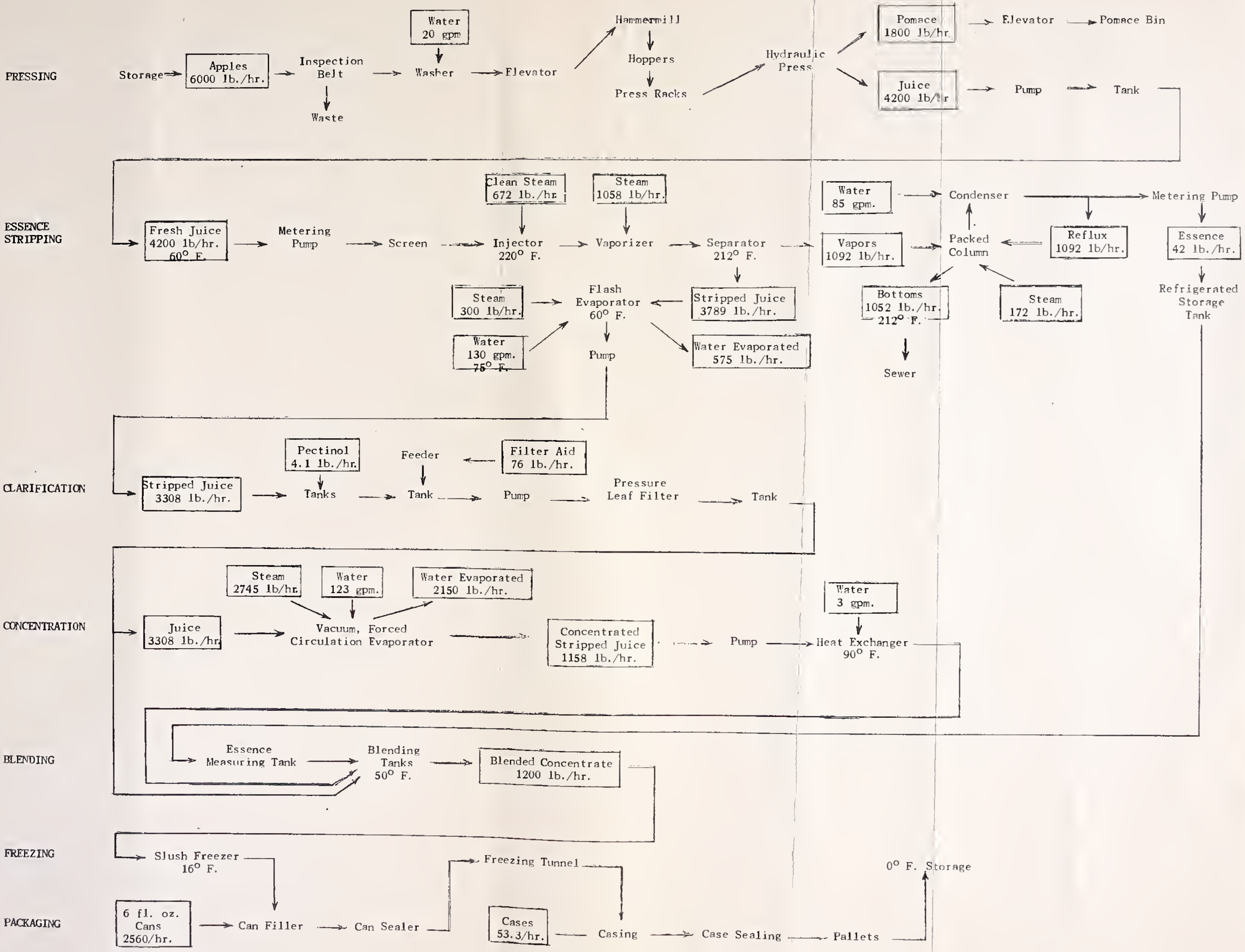
APPLE JUICE CONCENTRATE -- FLOW SHEET (Tentative)

Capacity: 3 tons of apples per hour.



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